WHAT IS CLAIMED IS:

1. A stable, phase-pure magnesium-substituted crystalline hydroxyapatite comprising from about 2.0 to about 29 wt% magnesium, wherein at least 75 wt% of the magnesium content is substituted for calcium ions in the hydroxyapatite lattice structure.

2. The phase-pure magnesium-substituted crystalline hydroxyapatite of Claim 1, comprising from about 3.5 to about 28.4 wt% magnesium.

3. The phase-pure magnesium-substituted crystalline hydroxyapatite of Claim 2, comprising from about 5 to about 25 wt% magnesium.

4. The phase-pure magnesium-substituted crystalline hydroxyapatite of Claim 1, wherein essentially all of the magnesium content is substituted for calcium ions in the hydroxyapatite lattice structure.

5. The phase-pure magnesium-substituted crystalline hydroxyapatite of Claim 1, comprising crystal agglomerates having a particle size between about 5 nm and about 100 microns.

6. A method for the preparation of phase-pure crystalline magnesium-substituted hydroxyapatite comprising mechanochemically reacting a source of calcium ions, a source of magnesium ions, a source of phosphate ions and a source of hydroxide ions, at least one of which is soluble in water, in a aqueous reaction medium until said magnesium substituted-hydroxyapatite is formed.

7. The method of Claim 6, wherein said ion sources are stoichiometrically selected to provide a predetermined level of magnesium substitution.

8. The method of Claim 6, further comprising the step of separating said magnesium-substituted hydroxyapatite from said aqueous reaction medium.

9. The method of Claim 8, further comprising the step of washing said magnesium-substituted hydroxyapatite with water.

10. The method of Claim 9, further comprising the step of drying said magnesium-substituted hydroxyapatite.

11. The method of Claim 9, further comprising the step of washing said magnesium-substituted hydroxyapatite with an aqueous ammonium citrate solution before washing said magnesium- substituted hydroxyapatite with water.

12. The method of Claim 6, wherein at least one of the ion sources is water-insoluble.

13. The method of Claim 12, wherein the calcium ion source or the magnesium ion source is water-insoluble.

14. The method of Claim 6, wherein said phosphate ion source is water soluble.

15. The method of Claim 6, wherein said magnesium ion source is selected from the group consisting of magnesium hydroxide, magnesium carbonate, magnesium halides, magnesium oxide, magnesium nitrate and magnesium phosphate.

16. The method of Claim 15, wherein said magnesium ion source is magnesium hydroxide.

17. The method of Claim 6, wherein said calcium ion source is selected from the group consisting of calcium hydroxide, calcium carbonate, calcium halides, calcium oxide, calcium nitrate and calcium phosphate.

18. The method of Claim 17, wherein said calcium ion source is calcium hydroxide.

19. The method of Claim 6, wherein said phosphate ion source is selected from the group consisting of ammonium phosphates, calcium phosphates, magnesium phosphates, and sodium phosphates.

20. The method of Claim 19, wherein said phosphate ion source is diammonium hydrogen phosphate.

21. A packing material for use in a chromatography column or gas sensor or as a catalytic support comprising the magnesium-substituted hydroxyapatite of Claim 1.

22. A biocompatible hard tissue implant comprising the magnesium-substituted hydroxyapatite of Claim 1.

23. The biocompatible hard tissue implant of Claim 22, comprising a metal or polymeric implant coated with said magnesium-substituted hydroxyapatite.

24. The biocompatible hard tissue implant of claim 22, comprising a polymeric composite.

25. A granular fill for direct incorporation into human or animal tissues comprising the magnesium-substituted hydroxyapatite of Claim 1.

26. The granular fill of claim 25, comprising a metal or polymeric composite for filling dental cavities.

27. A plant growth substrate comprising the magnesium-substituted hydroxyapatite of Claim 1.

28. A dentifrice composition comprising the magnesium-substituted hydroxyapatite of claim 1.

29. A method for increasing the magnesium content in the lattice structure of magnesium-substituted crystalline hydroxyapatite relative to the calcium content of the lattice structure and to the non-lattice magnesium content, said method comprising washing said magnesium-substituted hydroxyapatite with an aqueous ammonium citrate solution.

30. A host material for luminescent applications comprising the magnesium - substituted hydroxyapatite of claim 1.